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by N. W. Golchert

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SITE SURVEILLANCE AND MAINTENANCE PROGRAM
FOR PALOS PARK

Report for 1986

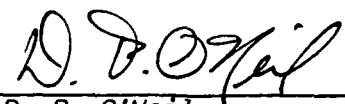
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SITE SURVEILLANCE AND MAINTENANCE PROGRAM FOR PALOS PARK

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Abstract

The results of the environmental monitoring program conducted at Site A/Plot M in the Palos Park Forest Preserve area for CY 1986 are presented. The monitoring program is the ongoing remedial action that resulted from the original radiological characterization of the site. The program consists of sample collection and analysis of air, surface and subsurface water, and bottom sediment to determine the migration pathway of water from the burial ground (Plot M) to hand-operated picnic wells, establish if buried radionuclides other than hydrogen-3 have migrated, and generally characterize the radiological environment of the area. The program was expanded late this year to study the migration of non-radiological hazardous waste constituents that may have been buried with the radioactive waste. This was done by analyzing borehole water samples for selected heavy metals and organic compounds. Earlier studies had determined that hydrogen-3 (as tritiated water) migrated from the burial ground and was present in minute concentrations in two nearby hand-pumped picnic wells. Hydrogen-3 in the Red Gate Woods picnic well continued to show the same pattern of elevated levels in the winter and low concentrations in the summer, but the magnitude of the winter peak was significantly less than in earlier years. Tritiated water continues to be detected in a number of wells, boreholes, and surface streams. For many years it was the only radionuclide found to have migrated. Recent measurements indicate the presence of strontium-90 in borehole water next to Plot M. However, the results of the program established that the radioactivity remaining at Site A/Plot M does not endanger the health or safety of the public visiting the site or those living in the vicinity.

1.0 Introduction

This report presents and discusses the monitoring data obtained during calendar year 1986. The program is the ongoing remedial action that resulted from the radiological characterization of the former site of Argonne National Laboratory and its predecessor, the University of Chicago's Metallurgical Laboratory, which was part of the World War II Manhattan Engineer District Project, in the Palos Park Forest Preserve southwest of Chicago, IL. The Laboratory used two locations in the Forest Preserve: Site A, a 19-acre area that contained experimental laboratory and nuclear reactor facilities; and Plot M, a 150 ft x 140 ft area used for the burial of radioactive waste. These locations are shown in Figures 1.1 and 1.2. To assist in understanding this report, reference should be made to the previous comprehensive reports on this subject,^(1,2) which provide greater detail and illustrations on sampling locations and descriptive material and give the results through 1981, and to the annual reports for 1982,⁽³⁾ 1983,⁽⁴⁾ 1984,⁽⁵⁾ and 1985.⁽⁶⁾ Earlier data will not be repeated in this progress report, but reference will be made to some of the results.

Operations at Site A began in 1943 and ceased in 1954. Among the research programs carried out at Site A were reactor physics studies, fission product separations, tritium recovery from irradiated lithium, and studies of the metabolism of radionuclides in laboratory animals. Radioactive waste and radioactively-contaminated laboratory articles from these studies were buried in Plot M. At the termination of the programs, the reactor fuel and heavy water, used for neutron moderation and reactor cooling, were removed and disposed of elsewhere. The containment shell and biological shield for the CP-2 and CP-3 reactors, together with various pipes, valves, and debris, were buried in place.

Burial of radioactive waste at Plot M began in 1944 and was discontinued in 1949. Waste was buried in six-foot deep trenches and covered with soil until 1948, after which burial took place in steel bins. The steel bins were removed in 1949, but the waste buried in trenches was allowed to remain in place. Concrete sidewalls, eight feet deep, were

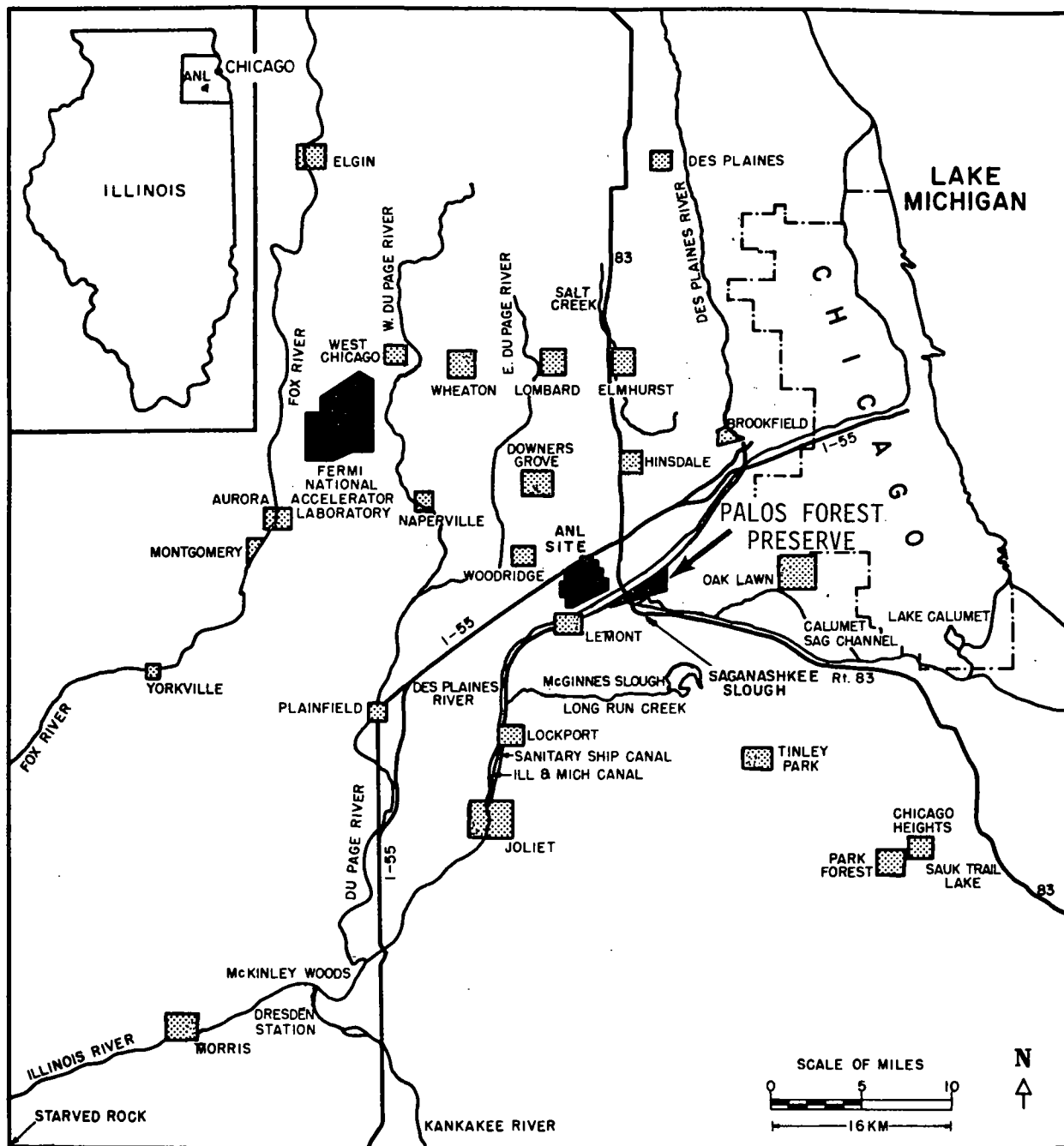


Figure 1.1 Location of Palos Forest Preserve on Chicago-Area Map

Non Responsive

poured around the perimeter of the burial area and a one-foot thick concrete slab was poured over the top. The concrete slab was covered with soil and seeded with grass. Both the Site A and Plot M areas were decommissioned in 1956. In 1973, elevated levels of hydrogen-3 (as water) were detected in two nearby hand-pumped picnic wells and found to be migrating from the burial plot into the surrounding soil and aquifers. As a result, an extensive radiological survey of the entire Palos Park site was conducted.

Geologically, Plot M is constructed on a moraine upland which is dissected by two valleys, the Des Plaines River valley to the north and the Sag valley to the south. The upland is characterized by rolling terrain with poorly developed drainage. Streams are intermittent and drain internally or flow to one of the valleys. The area is underlain by glacial till or drift, dolomite, and sedimentary rocks. The uppermost bedrock is Silurian dolomite, into which both the pre-existing picnic wells and some of the monitoring wells are placed and sampled as described in the text. The dolomite bedrock is about 200 feet thick. The overlying glacial till has a thickness that varies from 165 ft at Site A to zero at the Des Plaines and Calumet-Sag Channel, and some of the monitoring wells terminate in this layer. The depth to bedrock at Plot M is about 130 feet. Hydrologically, the surface water consists of swamps, ponds, and intermittent streams. The intermittent stream that drains Plot M flows from the highest point near Site A, past Plot M, then continues near the Red Gate Woods well (Fig. 1.2) and discharges, when there is sufficient water, into the Illinois and Michigan Canal. The ground water in the glacial till and dolomite forms two distinct flow systems (aquifers). The flow in the drift is controlled principally by topography. The flow in the dolomite is controlled by two discharge areas, the Des Plaines River to the north and the Calumet Sag Channel to the south. Water usage at the site is confined to the hand-pumped picnic wells, which are used only in the warmer seasons.

The climate is that of the upper Mississippi Valley, as moderated by Lake Michigan, and is characterized by cold winters and hot summers. Precipitation averages about 33 inches annually. The largest rainfalls occur between April and September. The average monthly temperature ranges from

21°F in January to 73°F in July. Approximately 7.9 million people reside within 50 miles of the site; the population within a five-mile radius is about 150,000. The only portion of the Forest Preserve in the immediate area of Plot M and Site A that is developed for public use is the Red Gate Woods picnic area (Fig. 1.2), although small numbers of individuals use the more remote areas of the Preserve.

The terminology used in previous reports is continued. A hole drilled and completed into the glacial till is called a borehole or core. The soil samples obtained from the hole are called soil cores. Some boreholes have been cased and screened to form monitoring wells. Water from such wells is called borehole water. Test wells drilled into the dolomite bedrock are called dolomite holes or deep holes. Water from such wells is called dolomite water. The hand pumped picnic wells, which are completed into or close to the dolomite bedrock, are called wells or picnic wells. They are identified by a location name or well number. These were in existence before this radiological and hydrological study of the area was begun.

The results of radioactivity measurements are expressed in this report in terms of picocuries per liter (pCi/L) and nanocuries per liter (nCi/L) for water, picocuries per cubic meter (pCi/m³) for air, and picocuries per gram (pCi/g) for soil and sediment samples. Radiation dose calculations are reported in units of millirem (mrem) or millirem per year (mrem/y). Other abbreviations of units are defined in the text.

2.0 Summary

The results of the ongoing environmental monitoring and surveillance program at the Palos Park site for calendar year 1986 are presented in this report. Sample collection and analyses were conducted on air, surface and subsurface water, and bottom sediment. Water vapor samples were collected over the stream bed upstream and downstream of the waste burial Plot and analyzed for tritium. Above ambient concentrations were found downstream of the Plot and are attributed to tritiated water leaching from the Plot and evaporating from the surface stream. The maximum dose from tritium in

air to a hypothetical individual who spends all of his time at the downstream location would be 0.005 mrem/y, or 0.005% of the applicable U. S. Department of Energy (DOE) Radiation Protection Standard of 100 mrem/y.

The tritiated water concentrations in the borehole and dolomite hole water were consistent with those observed in the past. Water from eight of 16 boreholes analyzed for strontium-90 contained concentrations greater than the detection limit of 0.25 pCi/L, which is considered the normal or ambient level. Elevated uranium concentrations in ten of the sampled boreholes were believed to be from the bentonite packing material and not from Plot M. However, the elevated strontium-90 levels found in some boreholes are probably from the Plot, since concentrations above 0.25 pCi/L have not been observed in the water from atmospheric fallout from Chernobyl or previous nuclear weapons testing, and no other source is known. If strontium-90, a relatively mobile cation, is migrating from the Plot, other radionuclides may follow. During the early years of this study only hydrogen-3, as tritiated water, was found outside the Plot.

Sampling of the five Forest Preserve picnic wells continued. Although the pattern of high tritium concentrations in the winter and low concentrations (less than the detection limit of 0.2 nCi/L) in the summer continued, the magnitude of the winter peak (3.4 nCi/L) and the annual average (1.3 nCi/L) in the Red Gate Woods well are significantly less than in earlier years. The corresponding values for the peak and average concentrations were 9.2 nCi/L and 4.8 nCi/L in 1982, 3.0 nCi/L and 2.2 nCi/L in 1983, 2.7 nCi/L and 1.2 nCi/L in 1984, and 2.5 nCi/L and 1.0 nCi/L in 1985. The well opposite Red Gate Woods showed the same pattern as in past years with maximum and minimum concentrations of 0.9 nCi/L and less than 0.2 nCi/L, respectively. The other wells were only occasionally greater than 0.2 nCi/L. If water equal to the Red Gate Woods well average concentration of 1.3 nCi/L were the sole source of water for an individual, the annual dose from tritium would be 0.26 mrem, compared to the U. S. Environmental Protection Agency (EPA) drinking water limit of 20 nCi/L and the corresponding annual dose of 4 mrem.⁽⁷⁾ This is 6% of the annual dose limit. Consumption of one liter of this water would produce a dose of 0.0003 mrem.

Surface water samples collected from the stream that flows around Plot M showed the same tritiated water concentration pattern as was observed in the past. Concentrations were at the ambient level (< 0.2 nCi/L) upstream of the Plot, increased to 50-400 nCi/L adjacent to the Plot, then decreased to 10-20 nCi/L further downstream. Other radiochemical analyses of water and stream-bed sediment collected above and below Plot M indicated that there are slightly higher concentrations of strontium-90 (in water only), cesium-137 (in sediment only), uranium (in water only), and plutonium-239 (in water and sediment) downstream. For both the water and sediment samples, the concentrations were very low.

The results of this program show that the radioactivity remaining at Palos Park does not endanger the health or safety of the public visiting the site or those living in the vicinity. The potential radiation doses are very low relative to the applicable standards.

3.0 Monitoring Program

The program is designed to monitor the elevated hydrogen-3 (as tritiated water) concentrations in some of the picnic wells in the Forest Preserve, determine the migration pathway of water from the burial ground to the wells, establish if other buried radionuclides or waste constituents have migrated, and characterize the radiological and non-radiological pollutant environment of the area. This is accomplished by analyses of water from all wells, boreholes, and surface streams in the area. Samples are collected from biweekly to annually, depending on past results and proximity to Plot M. During CY 1986, 382 samples were collected and 469 radiochemical analyses were performed. For the most part, individual results are presented in the tables, and compared to control, off-site, or upstream results. Where applicable, results are compared to appropriate standards such as the EPA drinking water standard.⁽⁷⁾ The Site A/Plot M program follows the guidance for monitoring at DOE facilities.⁽⁸⁾

The uncertainties associated with individual concentrations given in the tables are the statistical counting errors at the 95% confidence level. A few tables of tritium data do not contain these uncertainties, because

they were not carried in the data base that was used to prepare the computer-generated tables. In such cases, the following uncertainties apply:

<u>Concentration (nCi/L)</u>	<u>Uncertainty (% of Conc.)</u>
0.2-1.0	25-5%
1-10	5-1%
> 10	1%

3.1 Air

Water vapor samples were collected over the surface stream bed next to Plot M, since this stream drains leached tritiated water from the Plot, and analyzed for tritium to estimate the potential exposure from the atmospheric pathway. Samples were collected above and below Plot M and the results are given in Table 3.1. The concentrations were higher below Plot M than above, where the levels were similar to ambient tritium-in-air concentrations.⁽⁹⁾ During some of the sampling periods, water was not flowing in the stream, but above-ambient tritiated water vapor concentrations were observed below the Plot. As was also observed last year, the downstream concentrations in the fall were substantially lower than the spring values and may be due to higher than normal precipitation in the fall and generally higher stream concentrations in the spring. The dose to a hypothetical individual who breathed air continuously for one year at the maximum concentration of 10 pCi/m³ would be 0.005 mrem or 0.005% of the applicable DOE environmental dose limit of 100 mrem/y. This dose was calculated using the methodology specified in the DOE interim guidance⁽¹⁰⁾ for determining radiation exposures to members of the public in uncontrolled areas. The total quantity of radionuclide inhaled, in microcuries (μCi), is calculated by multiplying the air concentration by the general public breathing rate of 8400 m³/y.⁽¹¹⁾ This annual intake is then multiplied by the 50-year Effective Dose Equivalent Factor (EFF.D.E.) to obtain the dose. The EFF.D.E. for tritiated water vapor is 6.3×10^{-5} rem/μCi (rem per microcurie).

TABLE 3.1

Concentration of Tritiated Water Vapor Next to Plot M, 1986
(Concentrations in pCi/m^3)

Sampling Period	Location #1 [*] (Upstream)	Location #9 [*] (Downstream)
April 15 to April 18	1.8 ± 0.5	6.6 ± 0.6
April 21 to April 24	0.7 ± 0.5	5.1 ± 0.6
April 28 to May 1	0.6 ± 0.8	1.5 ± 0.8
May 5 to May 8	< 0.1	10.0 ± 1.0
May 12 to May 15	0.2 ± 0.9	6.3 ± 1.1
Spring Average	0.7 ± 0.6	5.9 ± 2.7
October 27 to October 30	1.4 ± 0.7	2.0 ± 0.7
November 3 to November 6	1.0 ± 0.5	1.3 ± 0.5
November 10 to November 13	0.2 ± 0.2	0.5 ± 0.2
November 17 to November 20	0.5 ± 0.4	0.6 ± 0.4
November 24 to November 26	0.2 ± 0.5	0.7 ± 0.4
Fall Average	0.7 ± 0.5	1.0 ± 0.6

^{*}See Figure 3.1.

3.2 Surface Water

Six sets of samples were collected from the stream that flows around Plot M. The sampling locations are shown in Figure 3.1. The samples were analyzed for tritiated water and the results are in Table 3.2. The same concentration pattern in the water flowing around Plot M was observed this year as in the past. Concentrations were low upstream of the Plot, increased as the stream flowed past the Plot, where it received tritiated water leaching out of the burial site, then decreased downstream due to dilution. The concentrations in the stream remained essentially the same as in previous years.

Large volume (20 liter) water samples were collected on April 18, 1986, and December 10, 1986, from this stream. Samples were collected above Plot M at Location #1 and from below Plot M at Location #9. These samples were analyzed for very low concentrations of radionuclides to determine if any had migrated out of Plot M and entered this surface stream. The results are given in Table 3.3. In addition to hydrogen-3, there may be elevated concentrations of strontium-90, uranium, and plutonium-239 at the downstream location. Both strontium-90 and uranium have been found in the past in Borehole #6 in Figure 3.2, between Plot M and the stream, and their presence in the stream would be another indicator of possible migration of these radionuclides.

3.3 Subsurface Water

3.3.1 Borehole Water

A number of the boreholes drilled in the Plot M area (Fig. 3.2) were cased with plastic pipe and screens installed (piezometers) to serve as sampling points within the till. Water samples were collected and water level measurements were made in these boreholes approximately monthly, weather permitting. The shallow boreholes responded to the spring precipitation as indicated by an increase in water levels followed by a drop during summer and fall when moisture was used for plant growth. The water

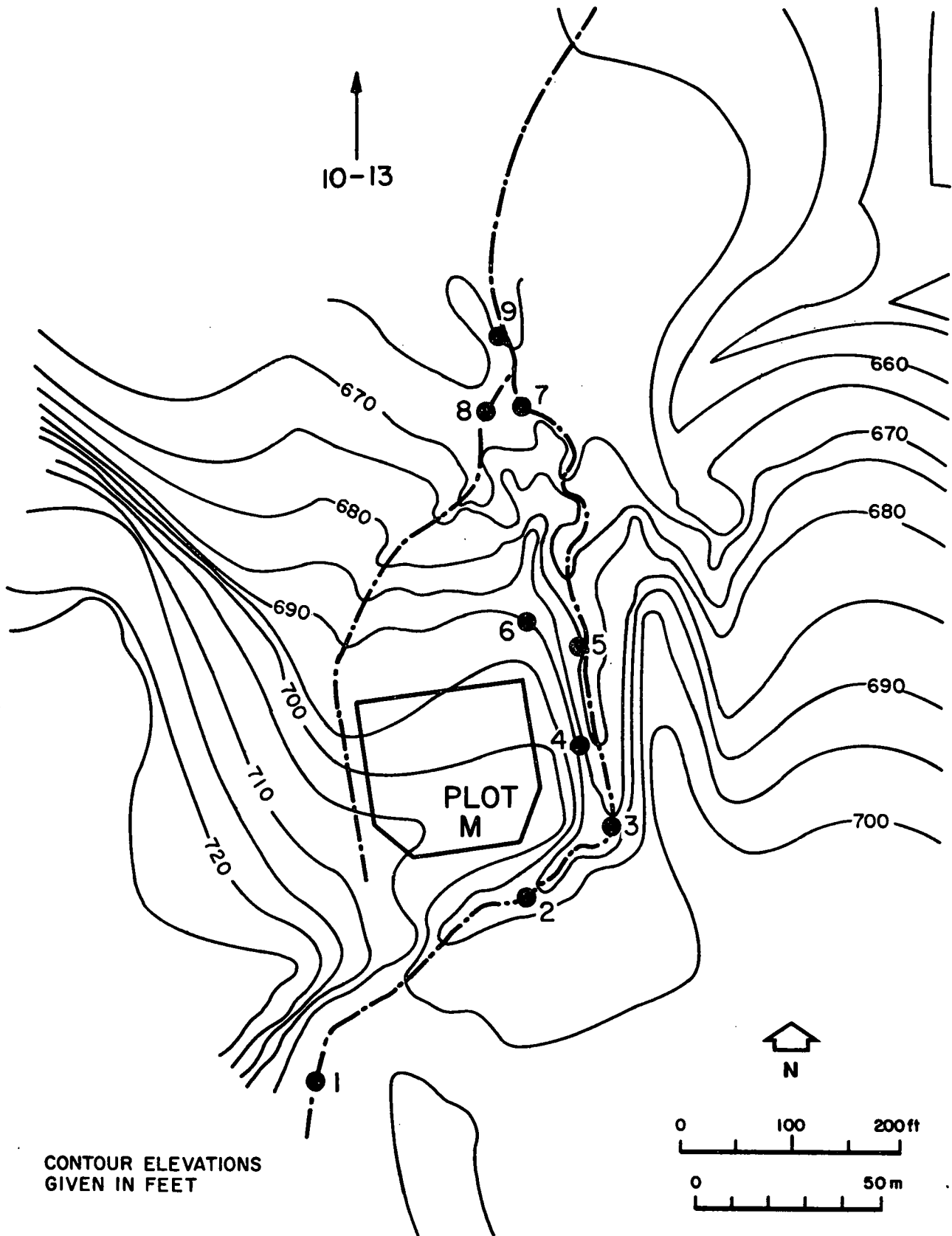


Figure 3.1 Surface Water Sampling Locations Near Plot M

TABLE 3.2

Tritiated Water Content of Surface Stream
Next to Plot M, 1986
(Concentrations in nCi/L)

Location Number*	Date Collected					
	March 17	April 18	July 1	October 7	October 30	December 10
1	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
2	0.3 ± 0.1	1.4 ± 0.1	1.2 ± 0.3	2.1 ± 0.2	1.3 ± 0.2	0.7 ± 0.2
3	27.6 ± 0.3	138.4 ± 0.6	47.7 ± 0.6	104.0 ± 0.7	76.0 ± 0.7	53.5 ± 0.6
4	26.6 ± 0.3	106.5 ± 0.6	50.7 ± 0.6	33.2 ± 0.4	43.2 ± 0.5	41.7 ± 0.5
5	31.0 ± 0.3	97.7 ± 0.5	46.3 ± 0.6	-	-	29.0 ± 0.4
6 (Seep)	77.5 ± 0.5	371.2 ± 1.0	63.0 ± 0.7	-	-	50.8 ± 1.6
7	40.3 ± 0.4	74.2 ± 0.5	-	26.8 ± 0.4	33.0 ± 0.5	42.3 ± 0.5
8	26.6 ± 0.3	175.0 ± 0.9	65.2 ± 0.7	-	-	40.8 ± 0.5
9	35.7 ± 0.5	78.4 ± 0.6	69.2 ± 0.7	17.8 ± 0.3	18.9 ± 0.4	37.7 ± 0.4
10	28.2 ± 0.5	36.7 ± 0.5	22.9 ± 0.5	13.0 ± 0.3	13.6 ± 0.3	18.9 ± 0.4
11	18.8 ± 0.4	18.9 ± 0.4	15.2 ± 0.4	-	7.8 ± 0.3	16.1 ± 0.4

*See Figure 3.1.

TABLE 3.3

Radioactivity Content of Stream Next to Plot M, 1986
(Concentrations in pCi/L)

Constituent	Date Collected	Location #1* (Upstream)	Location #9* (Downstream)
Total Alpha**	April 18	0.6 + 0.1	1.4 + 0.2
	December 10	1.2 \pm 0.2	1.6 \pm 0.2
Total Beta**	April 18	5.6 + 0.3	7.0 + 0.3
	December 10	5.0 \pm 0.2	5.8 \pm 0.2
Hydrogen-3	April 18	< 200	7.84×10^4 + 631
	December 10	< 200	3.77×10^4 \pm 401
Strontium-90	April 18	1.55 + 0.95	1.87 + 0.14
	December 10	0.91 \pm 0.14	1.51 \pm 0.12
Uranium-234	April 18	0.29 + 0.05	1.04 + 0.09
	December 10	0.19 \pm 0.06	0.74 \pm 0.12
Uranium-235	April 18	< 0.01	< 0.01
	December 10	< 0.01	< 0.01
Uranium-238	April 18	0.32 + 0.05	1.17 + 0.10
	December 10	0.20 \pm 0.06	0.84 \pm 0.12
Neptunium-237	April 18	< 0.001	< 0.001
	December 10	< 0.001	< 0.001
Plutonium-238	April 18	< 0.001	< 0.001
	December 10	< 0.001	< 0.001
Plutonium-239	April 18	0.0012 + 0.0006	0.0026 + 0.0009
	December 10	< 0.001	< 0.001
Americium-241	April 18	< 0.001	< 0.001
	December 10	< 0.001	< 0.001
Curium-242 and/or Californium-252	April 18	< 0.001	< 0.001
	December 10	< 0.001	< 0.001
Curium-244 and/or Californium-249	April 18	< 0.001	< 0.001
	December 10	< 0.001	< 0.001

* See Figure 3.1.

** Non-volatile.

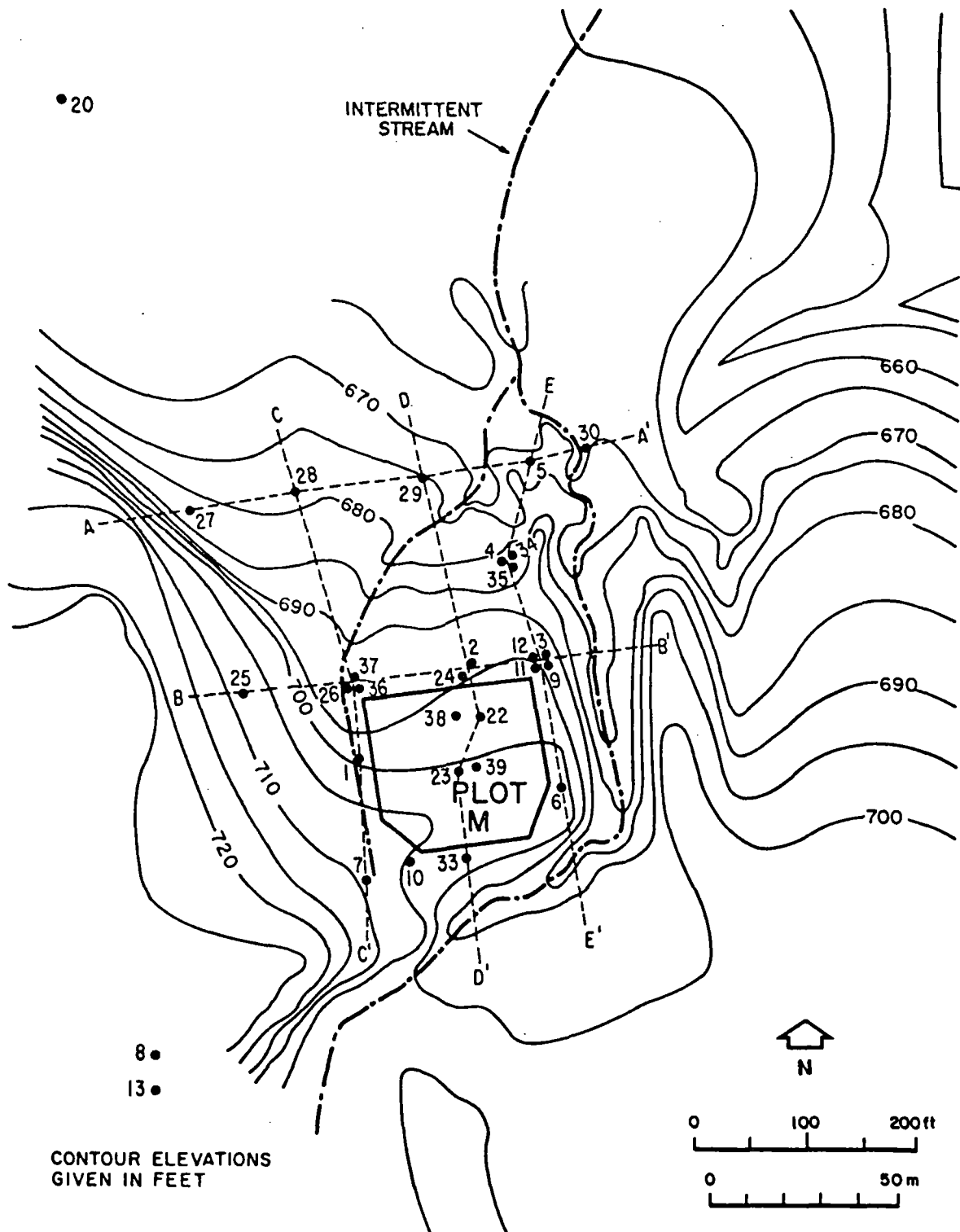


Figure 3.2 Map of Plot M Palos Site Showing Topography, Intermittent Stream and Borehole Locations

levels in the deeper boreholes (> 100 ft) were relatively constant throughout the year. Some boreholes were occasionally dry. All the water samples were analyzed for tritiated water and the results are collected in Table 3.4. Borehole #11 contains a nest of piezometers at three depths, 39 feet, 68 feet, and 124 feet. The piezometer at 68 feet was dry all year. The principal purpose of this arrangement is to obtain water level measurements at different depths to determine the vertical gradient of the hydraulic head.

The concentrations are consistent with those observed in the past. Low tritium concentrations correlate with high water levels, apparently a dilution phenomenon. The measured water levels in the boreholes are in Table 3.5. Since the measurement of the water levels is made relative to a benchmark at the top of the well casing, a decrease in numerical value indicates a rise in water level and dilution of the tritiated water. This is best illustrated by comparing the tritiated water concentrations in Borehole #6 over the year with the water level measurements. Higher tritiated water concentrations correlate with higher tritium concentrations in the soil cores obtained when the boreholes were constructed.

As part of a search for radionuclides other than tritium in the borehole monitoring wells, sets of large volume water samples were collected to obtain greater sensitivity in the analysis. One set of samples was collected early in July, while part of the second set was collected in late October, and the balance in December. Samples were collected from all boreholes that yielded sufficient water for analysis. All samples were analyzed for strontium-90 and the July samples were analyzed for isotopic uranium. The results are collected in Table 3.6. Strontium-90 concentrations greater than the detection limit of 0.25 pCi/L were found in eight of the 16 sampled boreholes, and such concentrations are believed due to migration from Plot M. Levels above 0.25 pCi/L would not be expected in this water from fallout, and no other source is known. It should be noted that the borehole with one of the highest strontium-90 concentrations (Borehole #6) is between the buried waste and the stream that flows around Plot M. As seen in Table 3.3, measurable strontium-90 concentrations were also found in the stream water below the Plot.

TABLE 3.4

Tritiated Water Content of Boreholes Near Plot M, 1986
(Concentrations in nCi/L)

Borehole	Depth (ft)	Date Collected							
		January 10	March 17	May 5	July 3	August 19	October 7	October 30	December 19
1	40	1461	941	1083	1198	1350	1432	1427	1437
2	40	-	359	386	425	464	467	464	360
3	40	4294	4399	4390	4304	4267	4301	4292	4179
4	40	401	463	741	681	708	718	679	681
5	40	108	103	110	106	107	110	112	110
6	40	21.6	22.8	296	536	604	184	345	33.6
8	40	-	-	-	2.2	-	-	< 0.2	-
9	40*	4263	2.43x10 ⁴	2.41x10 ⁴	4369	1.28x10 ⁴	2309	1.88x10 ⁴	2085
10	40*	-	-	3.20x10 ⁴	2.88x10 ⁴	2.66x10 ⁴	-	-	2.86x10 ⁴
11	39	208	664	314	1095	2760	2550	-	1650
11	124	63.8	63.1	67.1	70.2	86.9	90.2	104	80.1
24	125	-	7.2	14.9	35.1	75.3	38.1	61.2	82.0
26	60	-	2246	2170	2076	1948	1949	1970	1547
28	60	-	369	378	-	322	312	318	303
35	110	6943	6963	6210	4595	5715	6172	6564	4489
36	127	89.1	81.2	104	136	186	315	384	538

* Slant hole drilled at 45° to a depth of 40 ft below the surface.

slant
holes

TABLE 3.5

Water Level Measurements in Boreholes Near Plot M, 1986
(Units of feet below the benchmark at the top of the well)

Borehole	Depth (ft)	Date Measured							
		January 10	March 17	May 5	July 3	August 19	October 7	October 30	December 19
1	40	37.04	37.61	38.08	36.93	37.04	38.29	38.58	38.63
2	40	-	28.17	27.02	27.45	28.60	27.21	28.33	23.86
3	40	31.85	31.92	31.69	31.37	33.55	33.97	33.88	34.31
4	40	14.96	18.61	17.06	16.88	18.54	20.54	19.38	14.54
5	40	21.79	21.97	20.95	21.26	23.35	25.71	25.44	23.11
6	40	18.75	26.51	20.29	27.36	31.83	33.76	29.42	12.69
11	39	24.68	27.16	25.82	26.33	27.63	26.82	27.10	23.06
11	124	104.60	104.44	104.20	104.52	104.74	104.71	104.87	104.58
24	125	-	82.18	81.32	81.69	87.95	86.58	86.82	85.58
26	60	-	48.04	47.28	46.56	46.22	49.00	48.92	47.23
28	60	-	53.11	52.22	-	51.37	52.12	52.50	52.17
35	110	93.39	93.31	92.84	93.38	93.53	93.42	93.81	93.43
36	127	104.80	104.42	104.55	104.77	104.87	104.83	104.92	104.61

TABLE 3.6

Radiochemical Analyses of Borehole Water Samples Near Plot M, 1986
(Concentrations in pCi/L)

Borehole	Date Collected	Strontium-90	Uranium-234	Uranium-235	Uranium-238
1	July 3 December 19	0.53 ± 0.22 0.58 ± 0.27	7.15 ± 0.58 —	0.06 ± 0.06 —	6.60 ± 0.55 —
2	July 7 October 28	0.56 ± 0.22 0.56 ± 0.17	6.98 ± 0.49 —	0.06 ± 0.05 —	7.84 ± 0.52 —
3	July 3 October 28	< 0.25 < 0.25	3.53 ± 0.22 —	0.02 ± 0.02 —	1.95 ± 0.16 —
4	July 3 December 19	< 0.25 < 0.25	0.25 ± 0.06 —	< 0.01 —	0.21 ± 0.06 —
5	July 3 December 19	< 0.25 < 0.25	5.03 ± 0.34 —	0.05 ± 0.04 —	3.56 ± 0.29 —
6	July 3 October 28	6.08 ± 0.42 5.88 ± 0.20	1.25 ± 0.14 —	0.04 ± 0.03 —	1.23 ± 0.14 —
8	July 1 October 28	< 0.25 < 0.25	35.00 ± 2.06 —	— —	36.07 ± 2.08 —
9	July 3 December 19	7.15 ± 0.68 11.08 ± 0.64	3.77 ± 0.23 —	0.05 ± 0.03 —	3.72 ± 0.23 —
10	July 3 December 19	0.38 ± 0.39 < 0.25	7.47 ± 0.29 —	0.05 ± 0.03 —	7.34 ± 0.28 —
11 (39')	July 3 December 19	2.09 ± 0.40 4.59 ± 0.38	0.91 ± 0.11 —	0.02 ± 0.02 —	0.98 ± 0.12 —
11 (124')	July 3 December 19	1.83 ± 1.57 0.52 ± 0.17	0.61 ± 0.06 —	< 0.01 —	0.70 ± 0.06 —
24 (125')	July 7 December 19	< 0.25 < 0.25	0.31 ± 0.07 —	0.01 ± 0.01 —	0.24 ± 0.06 —
26	July 7 October 28	< 0.25 < 0.25	0.10 ± 0.04 —	< 0.01 —	0.09 ± 0.04 —
28	December 19	< 0.25	—	—	—
35	July 3 December 19	1.52 ± 0.73 0.38 ± 0.34	1.89 ± 0.20 —	< 0.01 —	1.75 ± 0.19 —
36	July 7 December 19	< 0.25 < 0.25	0.21 ± 0.06 —	< 0.01 —	0.27 ± 0.07 —

The uranium concentrations in some of the borehole water samples listed in Table 3.6 and some reported in earlier years were occasionally elevated. However, these high concentrations could not be correlated with proximity to Plot M. As discussed in last year's report,⁽⁶⁾ the uranium in the borehole water is from the bentonite packing material and not from migration from Plot M.

The entire set of borehole water samples collected early in July, was analyzed for iodine-129. Iodine is known to form very mobile anionic species that are poorly retarded by the soils. All samples had iodine-129 levels of less than the detection limit of 5 pCi/L. It is not known if any iodine-129 had been buried at Plot M, but fission product mixtures which contained iodine-129 were used at the site and some were probably buried.

DOE Order 5480.14⁽¹²⁾ requires the identification and characterization of any disposal site where chemically-hazardous waste may have been buried. Since various chemical wastes may have been buried along with the radioactive waste at Plot M, a program was established to determine if any such waste constituents were migrating from Plot M. Borehole water samples were collected on October 28, 1986, from six locations around Plot M. Five water samples were collected from boreholes on the perimeter of the Plot, Boreholes #1, #2, #3, #6, and #26, and from Borehole #8 which would serve as a control. The inorganic constituents in these samples were determined by flameless atomic absorption using pyrolytic graphite, flame atomic absorption, or ion chromatography and the organic constituents were determined by gas chromatography/mass spectrometry. The results of the measurements for selected inorganic constituents are in Table 3.7 and for the organic constituents, in Table 3.8.

Analyses were performed for a number of toxic metals and organic compounds that might be expected to be present in Plot M and the results were compared to the indicated limits. All the concentrations are well below any applicable limits, except sulfate. In addition, some other constituents were included in the tables for which no limits have been established. These are either constituents that are frequently found in chemical waste or were identified by the analytical method that was employed for the other

TABLE 3.7

Inorganic Constituents in Borehole Water, 1986
(Concentrations in mg/L)

Inorganic Constituent	Borehole Number [*]						Limit ^{**}
	1	2	3	6	8	26	
Arsenic	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	5.0
Barium	0.10	0.03	0.05	0.01	0.04	0.03	100
Cadmium	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	1.0
Calcium	560	438	122	94	516	244	-
Chloride	36.2	8.0	13.0	9.0	-	20.0	250
Chromium	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	5.0
Copper	0.05	0.14	< 0.01	0.01	0.03	0.18	-
Iron	< 0.05	< 0.05	< 0.05	< 0.05	0.60	< 0.05	-
Lead	0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01	5.0
Manganese	0.69	0.05	1.31	0.04	1.34	0.01	15
Mercury ^{***}	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	200
pH	7.3	7.0	7.1	7.1	6.9	11.3	-
Selenium	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	1.0
Silver	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	5.0
Sulfate	2363	902	225	72	2612	625	250
Zinc	0.03	0.02	< 0.01	< 0.01	< 0.01	< 0.01	

^{*} See Figure 3.2.

^{**} Based on 40 CFR Parts 261, 271, and 302.⁽¹³⁾

^{***} Concentrations in µg/L.

TABLE 3.8
Organic Constituents in Borehole Water, 1986
 (Concentrations in µg/L)

Organic Constituent	Borehole Number [*]						Limit ^{**}
	1	2	3	6	8	26	
Benzene	< 5	< 5	< 5	< 5	< 5	< 5	70
Ethylbenzene	< 5	< 5	< 5	< 5	< 5	< 5	-
m-Dichlorobenzene	< 5	< 5	< 5	< 5	< 5	< 5	10,800
m-Xylene	< 5	< 5	< 5	< 5	< 5	< 5	-
Monochlorobenzene	< 5	< 5	< 5	< 5	< 5	< 5	1400
o-Dichlorobenzene	< 5	< 5	< 5	< 5	< 5	< 5	4300
o-Xylene	< 5	< 5	< 5	< 5	< 5	< 5	-
p-Dichlorobenzene	< 5	< 5	< 5	< 5	< 5	< 5	10,800
p-Xylene	< 5	< 5	< 5	< 5	< 5	< 5	-
Perchloroethylene	< 10	< 10	< 10	< 10	< 10	< 10	100
Toluene	< 5	< 5	< 5	< 5	< 5	< 5	14,400
Trichloroethylene	< 10	< 10	< 10	< 10	< 10	< 10	70
1,2,4-Trichlorobenzene	< 5	< 5	< 5	< 5	< 5	< 5	-

^{*} See Figure 3.2.

^{**} Based on 40 CFR Parts 261, 271, and 302.⁽¹³⁾

constituents. The xylenes and ethylbenzene were common constituents of industrial wastes and trichlorobenzene is a frequent diluent of PCBs. The detection limit of these other organic constituents is considerably less than the most conservative limit, i.e., 70 µg/L, and therefore do not constitute a problem. Based on the sampling and analyses conducted on these samples, no hazardous waste constituents have been observed to be migrating from Plot M. These same six wells will be sampled in spring 1987 to verify those results.

3.3.2 Dolomite Hole Water

At the present time, 17 wells are cased into the dolomite zone to monitor the movement of any radionuclides in this aquifer. Most of the dolomite holes are located north of Plot M and east of the Red Gate Woods well Non Responsive, as shown in Figures 1.2 and/or 3.3. Four of these wells, DH 11 to DH 14, were installed in the spring and three wells, DH 15 to DH 17 in the fall of 1986 by the U. S. Geological Survey (USGS), as part of a cooperative study of this site. The wells installed in the fall are still being characterized and no water levels were measured or samples collected during 1986. Water was collected from the other wells on the same schedule as the boreholes. All samples were analyzed for tritiated water and the results are in Table 3.9. Water levels were also measured in the dolomite holes and these measurements are in Table 3.10. Since the four wells installed in the spring are located close to each other, the water level was only measured in DH 11 and assumed to be representative of the four.

The results of the tritiated water analysis of the first ten dolomite holes are consistent with concentrations measured in the past. In all, eight of the dolomite holes had elevated tritiated water concentrations. The highest tritium levels are in the six dolomite holes, DH 9 to DH 14, which are the furthest north and near the surface stream that flows next to Plot M (see Section 3.2). Several thin sand/gravel lenses are known to underlie the stream and may be hydraulically connected to the dolomite in this area. This would provide a supply of tritiated water from Plot M to maintain the elevated and relatively constant levels in these holes.

Non Responsive

TABLE 3.9

Tritiated Water Content of Dolomite Holes, 1986
(Concentrations in nCi/L)

Dolomite Hole	Date Collected								
	January 10	February 25	March 17	May 5	July 3	August 19	October 7	October 30	December 19
DH 1	< 0.2	< 0.2	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2
DH 2	< 0.2	< 0.2	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2
DH 3	1.64 ± 0.12	1.45 ± 0.12	1.61 ± 0.13	-	1.63 ± 0.10	-	1.57 ± 0.12	-	1.96 ± 0.14
DH 4	< 0.2	< 0.2	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2
DH 5	< 0.2	< 0.2	< 0.2	-	< 0.2	-	< 0.2	-	0.31 ± 0.10
DH 6	0.38 ± 0.10	0.36 ± 0.10	0.69 ± 0.10	0.67 ± 0.11	0.77 ± 0.11	0.81 ± 0.10	0.52 ± 0.10	0.52 ± 0.10	1.18 ± 0.12
DH 7	< 0.2	< 0.2	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2
DH 8	< 0.2	< 0.2	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2
DH 9	-	26.96 ± 0.29	26.74 ± 0.31	28.46 ± 0.33	26.22 ± 0.31	-	-	-	-
DH 10	7.02 ± 0.18	6.85 ± 0.17	7.41 ± 0.18	7.11 ± 0.17	6.78 ± 0.14	7.06 ± 0.17	7.49 ± 0.19	7.70 ± 0.21	7.29 ± 0.20
DH 11	-	-	8.23 ± 0.32	9.47 ± 0.20	9.48 ± 0.16	10.39 ± 0.19	10.30 ± 0.21	9.62 ± 0.20	9.63 ± 0.23
DH 12	-	-	7.19 ± 0.17	6.86 ± 0.18	6.99 ± 0.15	7.32 ± 0.17	8.43 ± 0.20	7.79 ± 0.19	-
DH 13	-	-	3.49 ± 0.13	4.36 ± 0.15	5.15 ± 0.13	5.04 ± 0.14	1.25 ± 0.12	2.80 ± 0.14	4.74 ± 0.17
DH 14	-	-	10.06 ± 0.19	9.41 ± 0.19	9.28 ± 0.16	10.18 ± 0.19	12.35 ± 0.23	11.71 ± 0.25	11.98 ± 0.25

TABLE 3.10

Water Level Measurements in Dolomite Holes, 1986
(Units of feet below the benchmark at the top of the well)

Dolomite Hole	Date Measured								
	January 10	February 25	March 17	May 5	July 3	August 19	October 7	October 30	December 19
DH 1	161.12	160.87	160.35	-	161.40	-	161.37	-	161.15
DH 2	139.53	139.16	138.55	-	139.76	-	139.62	-	139.46
DH 3	97.96	97.72	97.06	-	98.33	-	98.16	-	98.00
DH 4	93.23	93.85	92.26	-	93.50	-	93.35	-	93.08
DH 5	78.20	77.87	77.21	-	78.46	-	78.34	-	78.06
DH 6	75.18	74.80	74.19	75.10	75.36	75.80	75.18	75.50	74.97
DH 7	82.29	82.10	81.70	-	82.35	-	82.43	-	82.24
DH 8	74.84	74.66	74.48	-	74.84	-	75.00	-	75.03
DH 9	74.12	73.77	73.10	73.63	74.64	74.97	74.11	73.63	74.01
DH 10	64.69	64.23	63.67	64.52	64.78	65.41	64.73	65.22	64.43
DH 11	-	-	-	75.66	75.93	76.58	75.89	76.36	75.60

DH 9 and DH 11 are located about ten feet apart, but have significantly different tritiated water concentrations. DH 9 may not be properly seated into the dolomite since collapse of the lower hole wall has plugged the hole with material to a level such that no samples could be obtained during the second half of the year. In contrast, DH 11 is drilled to 225 feet and has only about one-third of the tritium measured in DH 9. It is concluded that the tritiated water is moving at the till-dolomite interface or in the uppermost fractures of the dolomite. Since DH 11 is drilled much deeper, water from the lower part of the hole is diluting the contribution from the upper fractures, resulting in a lower net tritium concentration. Results for DH 6 and DH 13 showed a decrease between the August 19 and October 7 samples. This was possibly due to construction of DH 17 and packer tests on other nearby wells. The tritiated water content of DH 6 is slightly elevated and is probably located on the fringe of the plume intercepted by the wells to the north. The other dolomite hole with elevated tritium is DH 3, which is immediately downgradient from Plot M. Previous analysis of soil core samples indicated the presence of tritium down to the till-dolomite interface.

3.3.3 Well Water

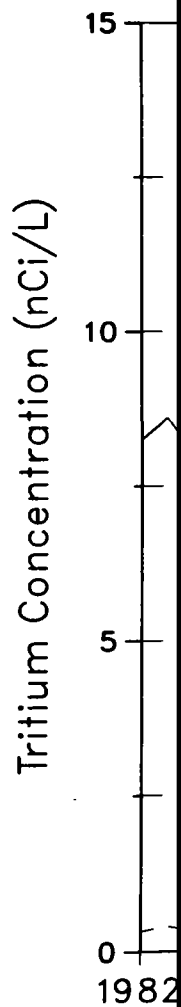
Sampling was conducted throughout the year at the five Forest Preserve picnic wells located north of Plot M and shown in Figure 1.2. These wells are located in the same dolomite rock zone as the previously discussed dolomite holes. All the samples were analyzed for tritiated water and the results are listed in Table 3.11. The Red Gate Woods well Non Responsive continues to reach a maximum in the fall and winter and a minimum in the summer, while the well opposite Red Gate Woods well Non Responsive shows a maximum in the spring and a minimum in the fall. However, the magnitude of the winter peak in the Red Gate Woods well Non Responsive is significantly less than in earlier years and has been trending downward over the last few years. This is illustrated in Figure 3.4 which shows a plot of the individual results for the past five years. The other wells, although also downgradient from Plot M, are evidently too far from the Plot to show consistent elevated tritium concentrations, although occasional results are above the detection limit. A set of picnic well water samples was collected on April 17, 1986, from

TABLE 3.11

TRITIATED WATER CONTENT IN WELLS NEAR SITE A /PLOT M, 1986
(CONCENTRATIONS IN NANOCURIES/L)

DATE COLLECTED	WELL NUMBER				
	5167	5159	5158	5157	5215
JANUARY 8, 1986	0.23	0.62	< 0.2	< 0.2	< 0.2
JANUARY 22, 1986	0.22	0.94	-	-	-
FEBRUARY 12, 1986	2.2	0.82	< 0.2	< 0.2	< 0.2
FEBRUARY 19, 1986	2.0	0.52	-	-	-
MARCH 12, 1986	2.4	0.70	< 0.2	< 0.2	< 0.2
MARCH 19, 1986	2.2	0.61	-	-	-
APRIL 2, 1986	0.73	0.70	-	< 0.2	0.26
APRIL 16, 1986	0.24	0.68	-	-	-
MAY 7, 1986	0.21	0.83	< 0.2	< 0.2	< 0.2
MAY 21, 1986	< 0.2	0.78	-	-	-
JUNE 4, 1986	< 0.2	0.72	< 0.2	< 0.2	-
JUNE 18, 1986	< 0.2	0.56	-	-	-
JULY 2, 1986	0.21	0.64	0.25	0.26	-
JULY 16, 1986	0.52	0.69	-	-	-
AUGUST 13, 1986	0.37	0.66	< 0.2	< 0.2	-
AUGUST 27, 1986	0.55	0.48	-	-	-
SEPTEMBER 3, 1986	0.52	0.43	< 0.2	< 0.2	-
SEPTEMBER 17, 1986	1.9	0.58	-	-	-
OCTOBER 1, 1986	2.9	0.56	< 0.2	< 0.2	< 0.2
OCTOBER 15, 1986	3.4	0.46	-	-	-
NOVEMBER 5, 1986	1.9	0.60	< 0.2	< 0.2	< 0.2
NOVEMBER 19, 1986	1.7	0.84	-	-	-
DECEMBER 3, 1986	2.8	0.76	0.28	0.24	0.22
DECEMBER 17, 1986	2.9	0.82	-	-	-

Non Responsive



Non Responsive

All the tritium results were less than the detection limit of 0.2 nCi/L.

The Red Gate Woods well **Non Responsive** is the location that provides the greatest potential radiation exposure to the public. If water equal to the Red Gate Woods well average concentration of 1.3 nCi/L were the sole source of water for an individual, the annual dose from the tritium would be 0.26 mrem. This is based on the EPA drinking water limit of a dose of 4 mrem/y, which results from the consumption of two liters per day of water at a concentration of 20 nCi/L.⁽⁷⁾ If an individual consumed one liter of this water, the dose would be 0.0003 mrem. These doses are very low compared to the EPA limit.

In addition to tritiated water measurements, several well water samples were analyzed for isotopic uranium, total alpha, total beta, strontium-90, and the transuranic nuclides. The total alpha and total beta activities were in the normal range of concentrations found in other wells completed into the dolomite, the strontium-90 results were all less than the detection limit of 0.25 pCi/L and the transuranic nuclides were all less than the detection limit of 0.001 pCi/L. The uranium results are presented in Table 3.12. The range of concentrations is similar to that found previously. The elevated uranium concentrations found in the Red Gate Woods well **Non Responsive** near the end of 1985⁽⁶⁾ were not observed this year. The reason for the higher results in late 1985 is not known.

Samples were collected quarterly from the Red Gate Woods well **Non Responsive** and analyzed for the same inorganic constituents discussed in Section 3.3.1. The results are found in Table 3.13. Because the picnic wells are used as a drinking water supply, the limits used were the State of Illinois concentrations of chemical constituents in drinking water.⁽¹⁴⁾ As discussed earlier, the constituents in Table 3.13 that do not have a specific limit are provided for completeness. Although the limits are occasionally exceeded for lead and manganese, these concentrations are probably due to natural causes. Elevated levels of iron, zinc, and some trace metals can sometimes be related to the decomposition of the well pump materials.

Non Responsive

TABLE 3.13

Inorganic Constituents in Red Gate Woods Well Water, 1986
(Concentrations in mg/L)

Inorganic Constituent	Number of Samples	Average	Minimum	Maximum	Limit ⁽¹⁴⁾
Arsenic	4	-	-	< 0.005	0.05
Barium	4	0.076 \pm 0.073	0.033	0.142	1.0
Cadmium	4	0.002 \pm 0.002	< 0.001	0.003	0.01
Chloride	4	5.525 \pm 8.477	< 0.100	13.000	250
Chromium	4	0.005 \pm 0.003	0.003	0.007	0.05
Copper	4	0.280 \pm 0.748	0.002	1.088	-
Fluoride	4	0.106 \pm 0.027	0.088	0.132	-
Iron	4	13.043 \pm 12.571	7.438	26.471	-
Lead	4	0.070 \pm 0.152	0.010	0.234	0.05
Manganese	4	0.087 \pm 0.073	0.032	0.156	0.15
Mercury*	4	-	-	< 0.050	2.0
Nickel	4	0.015 \pm 0.020	0.002	0.028	-
pH	4	-	7.0	7.2	-
Selenium	4	-	-	< 0.005	0.01
Silver	4	-	-	< 0.001	-
Sulfate	4	307 \pm 105	214	397	250
Zinc	4	12.215 \pm 3.180	10.389	15.543	-

* Concentrations in $\mu\text{g/L}$.

There is no evidence that the source of the elevated inorganic constituents is from Plot M.

3.4 Bottom Sediment

Bottom sediment samples were collected from the stream next to Plot M at Location #1 and at Location #9 on April 18, 1986, and December 10, 1986. These samples were taken at the same times and locations as the water samples discussed in Table 3.3. Various radiochemical analyses were performed on these samples and the results are found in Table 3.14. All results are similar at both locations except that the cesium-137 and plutonium-239 are slightly elevated downstream. The plutonium-239 concentration of 0.043 pCi/g, is slightly above the expected fallout level and may be a reflection of the slightly elevated plutonium content in water at that location (Table 3.3). The downstream cesium-137 may also be from Plot M, but the concentrations are very low and may reflect differences in the retentiveness of the bottom material.

TABLE 3.14

Radioactivity Content of Stream Bed Next to Plot M, 1986
(Concentrations in pCi/g)

Radionuclide	Date Collected	Location #1* (Upstream)	Location #9* (Downstream)
Potassium-40	April 18	22.89 + 0.74	17.72 + 0.61
	December 10	20.74 ± 0.80	18.34 ± 0.61
Strontium-90	April 18	0.20 + 0.16	0.17 + 0.04
	December 10	0.14 ± 0.09	0.14 ± 0.06
Cesium-137	April 18	0.18 + 0.02	0.41 + 0.03
	December 10	0.10 ± 0.02	0.40 ± 0.03
Radium-226	April 18	2.20 + 0.08	1.88 + 0.08
	December 10	1.69 ± 0.07	2.08 ± 0.07
Thorium-228	April 18	1.17 + 0.04	1.00 + 0.04
	December 10	1.24 ± 0.04	0.98 ± 0.04
Thorium-232	April 18	1.07 + 0.10	0.95 + 0.09
	December 10	1.01 ± 0.10	0.88 ± 0.09
Uranium-234	April 18	1.35 + 0.05	1.36 + 0.05
	December 10	1.16 ± 0.07	1.29 ± 0.08
Uranium-235	April 18	0.01 + 0.01	< 0.01
	December 10	0.03 ± 0.01	< 0.01
Uranium-238	April 18	1.55 + 0.06	1.45 + 0.05
	December 10	1.25 ± 0.08	1.49 ± 0.08
Plutonium-238	April 18	0.0002 + 0.0001	0.0010 + 0.0001
	December 10	< 0.0001	0.0009 ± 0.0003
Plutonium-239	April 18	0.0053 + 0.0003	0.0426 + 0.0007
	December 10	0.0022 ± 0.0003	0.0467 ± 0.0017
Americium-241	April 18	0.0018 + 0.0003	0.0009 + 0.0002
	December 10	0.0009 ± 0.0004	0.0030 ± 0.0007

* See Figure 3.1.

4.0 References

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- (7) U. S. Environmental Protection Agency, "Interim Primary Drinking Water Regulations - Radionuclides," 40 CFR Part 141, Federal Register, 41, pp. 28402-28409, July 1976 (also available as Report EPA-570/9-76-003).
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5.0 Appendices

5.1 Quality Assurance Program

All nuclear instrumentation is calibrated with standard sources obtained from the U. S. National Bureau of Standards (NBS), if possible. If NBS standards were not available for particular nuclides, standards from the Amersham Corporation were used. The equipment is usually checked on a daily basis with secondary counting standards to insure proper operation. Samples were periodically analyzed in duplicate or with the addition of known amounts of a radionuclide to check precision and accuracy. Intercomparison samples distributed by the Quality Assurance Branch of the EPA are analyzed regularly. In addition, our laboratory participates in the DOE Environmental Measurements Laboratory Quality Assurance Program, a semi-annual distribution of four or five different sample matrices containing various combinations of radionuclides. The results of our participation in both programs for 1986 are published in ANL-87-9.⁽⁹⁾

Many factors enter into an overall quality assurance program other than the analytical quality control discussed above. Representative sampling is of prime importance. Appropriate sampling protocols are followed for each type of sampling being conducted. Water samples are pre-treated in a manner designed to maintain the integrity of the constituent sought. For example, samples for trace radionuclide analyses are acidified immediately after collection to prevent hydrolytic loss of metal ions.

5.2 Applicable Standards

The principle standard that is applicable to this study is the EPA drinking water standard as applied to the Forest Preserve wells. All other water samples; surface stream, deep holes, and boreholes, are not drinking water supplies and therefore this standard does not apply. Since tritiated water is the only radionuclide identified in the Forest Preserve wells, the EPA limit of 20 nCi/L, which would result in an annual dose of 4 mrem, applies. The DOE interim guides⁽¹⁰⁾ are applied to the other

measurements. These EFF.D.E.s are based on a radiation protection standard of 100 mrem/y.

5.3 Analytical Methods

The analytical methods used to obtain the data in this report are the same as those described in ANL-87-9.⁽⁹⁾

5.4 Acknowledgements

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